

Comment on "Disorder and Quantum Fluctuations in Superconducting Films in Strong Magnetic Fields" :

In a recent paper [1], Galitski and Larkin (GaL) have examined a macroscopic superconducting (SC) transition field H_c at zero temperature ($T = 0$) in disordered thin films under magnetic fields perpendicular to the plane. They have argued that H_c usually lies *above* the ordinary mean field $\overline{H}_{c2}(0)$ at $T = 0$ and that an upwardly curved *nominal* $H_{c2}(T)$ curve defined from resistivity data [2,3] can be explained based on this $T = 0$ result.

Here, based on our recent works [4,5], we mainly focus on the situation denoted in Ref.1 as the mesoscopic disorder case and point out that the GaL's conclusion $H_c > \overline{H}_{c2}(0)$ contradicts available experimental data [6,7] suggesting a field-tuned superconductor-insulator transition (FSIT) and that this failure can be ascribed to their neglect of the amplitude-dominated quantum superconducting (AQSC) fluctuation. When arguing that the transition dominated by the disorder-induced SC islands with local H_{c2} -values much higher than $\overline{H}_{c2}(0)$ can occur at H_c much above $\overline{H}_{c2}(0)$, GaL have assumed that the AQSC fluctuation may be important only near $\overline{H}_{c2}(0)$ so that an SC transition at H_c may occur without being disturbed by the AQSC fluctuation. Since the correlator C used in Ref.1 in defining H_c diverges when the Edward-Anderson order parameter becomes nonvanishing, their H_c should be identified with an FSIT field within the model in Ref.1. However, resistance data in 2D SC samples show a negative magnetoresistance [6,7] in higher fields than an (apparent) FSIT field, and this behavior is not seen [6] in 2D films nonsuperconducting even in zero field and in 3D SC samples. As pointed out elsewhere [4], this is best understood as the presence, *above* the (apparent) FSIT field, of nonvanishing fluctuation conductance terms [8] excluded from the Ginzburg-Landau description. Namely, the FSIT behavior occurs, contrary to the result in Ref.1, within or below the region around $\overline{H}_{c2}(0)$ in which the AQSC fluctuation is violent.

In our opinion, an AQSC fluctuation peculiar to each of such islands with a higher H_{c2} -value begins to become important above $\overline{H}_{c2}(0)$ consistently. A consistent treatment between the AQSC fluctuation and the vortex pinning effect has led to a $T = 0$ FSIT field lower than $\overline{H}_{c2}(0)$ [4,5]. We also note that, contrary to the data [2,6,7], GaL's eq.(16) results in an H_c increasing with increasing disorder. According to Ref.5, an interplay between a microscopic disorder and an electron-electron repulsion needs to be incorporated to explain the FSIT field decreasing with increasing disorder.

Regarding the resistive $H_{c2}(T)$ increasing upwardly upon cooling in 2D like systems [2], we note that, if the SC fluctuation at measured temperatures is mainly not quantum but thermal in character, such an upward curve will be explained in terms of the SC fluctuation theory [9]

by phenomenologically incorporating a pinning strength through a random T_c . For instance, by defining a resistive $H_{c2}(T)$ in the manner $\rho(H = H_{c2}) = 0.9\rho_n$, where ρ and ρ_n are, respectively, the total and normal resistivities, the resulting resistive $H_{c2}(T)$, in contrast to the GaL's strong disorder case, may lie below $\overline{H}_{c2}(T)$ and deviate upwardly at low enough T from a nearly linear behavior [2] as a consequence of a decrease upon cooling of the SC fluctuation strength relative to the pinning strength. Further, if a resistive $H_{c2}(T)$ in 3D systems [3] with strong SC fluctuation is defined as the positions at which the resistance (apparently) vanishes, it should also show an upwardly curved line below $\overline{H}_{c2}(T)$ reflecting the 3D vortex glass fluctuation created by the thermal or quantum SC fluctuation. Heat capacity data [10] and recent resistivity data [11] for overdoped cuprates strongly suggest $\overline{H}_{c2}(T)$ lying far above the upwardly-curved [3] resistive $H_{c2}(T)$. Similar remarkable differences between two nominal $H_{c2}(T)$ defined, respectively, from resistivity and other quantities are also found in electron-doped [12] and (hole-)underdoped [13] cuprates. Through such recent data in SC cuprates, it is believed that an upward resistive $H_{c2}(T)$ -curve is not a reflection of the GaL's $T = 0$ result in their strong disorder case but a direct consequence of SC fluctuation effects at nonzero T .

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